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Native Species Establishment on an Oil Drill Pad Site in the Uintah Mountains, Utah: Effects of Introduced Grass Density and Fertilizer

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RESEARCH SUMMARY

The effects of introduced grass seeding density and fertilizer on native species establishment were examined on an oil drill pad site in the Uintah Mountains, UT. Seeding density treatments consisted of seeding native species at a rate of 215/m^2 with three levels of introduced grasses: (1) none, (2) 215/m^2, and (3) 545/m^2. The fertilization treatments were nonfertilization and a one-time fertilization that consisted of 56 kg/ha of N applied as NH_4NO_3, 56 kg/ha of P applied as P_2O_5, and 28 kg/ha of K applied as K_2O. Increasing introduced grass seeding density resulted in significantly higher introduced grass biomass ($p < 0.05$), but native biomass showed no response and colonizer biomass decreased ($p < 0.05$). Of the seeded introduced grasses, smooth brome, intermediate wheatgrass, and orchardgrass had consistently higher biomass than meadow foxtail and Timothy. The native species, slender wheatgrass, muttongrass, tufted hairgrass, and western yarrow had high establishment, while spike trisetum, everlasting, silky phacelia, serviceberry, mountain big sagebrush, and Woods rose exhibited poor establishment. Two years after fertilization there were no significant differences in soil NO_3–N or exchangeable K between fertilized and unfertilized treatments, but significantly higher available soil P in fertilized treatments ($p < 0.01$). Fertilization resulted in significantly higher biomass of introduced grasses, natives, and colonizers in year 1 ($p < 0.001$), but by year 3 there were no significant differences between fertilized and unfertilized treatments for any of the species. Native species biomass exibited less extreme responses to the one-time fertilizer application than introduced grasses and showed relatively larger yearly increases in unfertilized treatments. During the 3-year study colonizer biomass exhibited large yearly declines regardless of fertilizer treatment ($p < 0.01$). Methods used in the revegetation of similar sites should be determined by the inherent regenerative capacity of the site and the desired end land use.

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Native Species Establishment on an Oil Drill Pad Site in the Uintah Mountains, Utah: Effects of Introduced Grass Density and Fertilizer

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INTRODUCTION

Native species are widely used in mined land reclamation to meet legal requirements. The Surface Mining Control and Reclamation Act (SMCRA) of 1977 requires the use of native species for coal mine revegetation unless introduced species are specifically approved by the regulatory authority. Individual State regulations for coal mining operations must equal or exceed those of SMCRA. Noncoal mining is governed solely by the States, and large differences exist in the regulations. In Utah the regulations for noncoal mines or other disturbances have no requirements for native species.

Ecologically, native species have many desirable attributes for disturbed land reclamation. In extreme environments such as harsh climates and toxic spoils, natives may be the only species capable of surviving and reproducing. Including native species in seeding mixtures can enhance species diversity and may accelerate successional processes. Diversity has been correlated with long-term stability and productivity (Root 1973; Tahvanainen and Root 1972), and ecosystems with several types of species are more likely to persist following natural disturbances such as grazing and fire (Harper 1977; McNaughton 1977; Mellinger and McNaughton 1975). In addition, vegetation diversity is frequently correlated with the diversity of animal species (Southwood and others 1979).

Knowledge of the establishment characteristics of native species is essential for the successful reclamation of disturbed land with these species. When native species are included in a seeding mixture, they are often sown with rapidly growing introduced species. Studies that have examined the interactions between natives and introduced species indicate that seeding density, species composition of the seeding mixture, and rate and frequency of fertilization affect native species establishment and ultimate stand composition (Brown and others 1984; DePuit and Coenenberg 1979).

Introduced and cultivated species frequently have higher growth rates, lower root to plant ratios, and higher nutrient uptake efficiency than native species (Chapin 1980). Given the proper growing conditions, these species exhibit highly positive growth responses to N and P fertilization (Aldon and others 1976; DePuit and others 1978; Hanson and others 1976; Hodder and others 1972; Houston and Hyder 1975). At high rates of fertilization species that exhibit the greatest growth response, frequently annuals and introduced grasses, tend to outcompete slower growing natives (Berg 1980; DePuit and Coenenberg 1979). In addition, N-fixing legumes often show a negative response to high levels of N fertilization when growing in mixtures with grasses (DePuit and Coenenberg 1979). The frequency of fertilization also affects individual species' responses and, ultimately, stand composition (Brown and others 1984). Repeated fertilizer application can stimulate introduced species production over long periods. Native species development in stands that include introduced species is often greatest under no and first-year fertilization.

This study addressed the question: What effects do seeding density of introduced grasses and fertilization have on establishment and growth of native grasses, forbs, and shrubs? I tested three null hypotheses: (1) increasing density of introduced grasses would not lower establishment and growth of native grasses, forbs, and shrubs; (2) fertilization would not have a larger positive effect on the establishment and growth of introduced grasses than on the establishment and growth of native species; and (3) fertilization would not compound the negative effects of increasing introduced grass density on the establishment and growth of native species. I then related the findings of this study to possible reclamation strategies for this and similar sites.

METHODS

The study site is in the northeastern corner of Utah on the north slope of the Uintah Mountains (S24, T3N, R14E) at approximately 2,743 m. The site is in a small basin, 1.2 to 1.6 ha, that was used as an oil drilling pad site by Phillips Oil Company. The company recontoured the basin leaving two sloping faces on the southern end, a large mound on the east, and a small pond on the north. The study plots are in the center of the basin on homogeneous (5 percent slope) terrain.

The soil on the site is a well-drained sandy loam derived from quartzite and sandstone. Average annual precipitation is about 64 cm with April and May the wettest months and precipitation fairly evenly distributed

among the other 10 months (Bengeyfield and others 1980). The vegetation surrounding the area is dominated by lodgepole pine (*Pinus contorta*) with a sparse understory of species such as Oregon-grape (*Berberis repens*) and mountain lover (*Pachystima myrsinites*). Small patches of aspen (*Populus tremuloides*) are interspersed throughout the lodgepole pine, and broad meadows with species such as tufted hairgrass (*Deschampsia cespitosa*) and muttongrass (*Poa fendleriana*) follow the major drainages.

Study Design

The study included three seeding density treatments and two fertilizer treatments in a randomized block design with three replications of each treatment. Each replication was 6.1 by 30.5 m. The density treatments consist of a constant density of natives (215/m^2) seeded with (1) no introduced grasses, (2) an equivalent density of introduced grasses (215/m^2), and (3) three times the density of introduced grasses (645/m^2) (table 1). Seeding densities were based upon pure live seed (PLS) and determined from recommended levels of seeding densities for mined land revegetation in general and for seeding mixtures of natives specifically (USDA FS 1979).

The fertilization treatments I chose were nonfertilization and an "optimal" level. I based the "optimal" level on the recommendations of Tiedemann and Lopez (1982) and took into account the initial levels of N, P, and K in the soil. The levels and forms of nutrients were 56 kg/ha of N applied as NH_4NO_3, 56 kg/ha of P applied as P_2O_5, and 28 kg/ha of K applied as K_2O.

Seeding Mixture

Table 1 contains a complete list of the species used in this study. The introduced grasses were chosen on the basis of their ability to perform well under climatic and edaphic conditions similar to those that exist on the study site (Thornburg 1982). I selected native species that were colonizers on similar disturbed sites in the area.

Seeds of introduced grasses, native shrubs, and western yarrow were purchased. Seeds of the other native species were collected adjacent to the study site during the fourth week of August, allowed to dry for 1 week, and then threshed. Seed weight and number per gram were determined by weighing three replications of 100 seeds of each species. Seed viability of the collected native species was determined from a standard tetrazolium test (Moore 1972). Collected native seeds were about 99 percent pure.

Table 1—Numbers of pure live seeds for native and introduced species used in each treatment

Species	Natives only	Natives and low density introduced	Natives and high density introduced
		Pure live seed/m^2	
Introduced grasses			
Intermediate wheatgrass (*Agropyron intermedium*)	0	43	129
Meadow foxtail (*Alopecurus pratensis*)	0	43	129
Smooth brome (*Bromus inermis*)	0	43	129
Orchardgrass (*Dactylis glomerata*)	0	43	129
Timothy (*Phleum pratense*)	0	43	129
Subtotal	0	215	645
Native species			
Grasses			
Slender wheatgrass (*Agropyron trachycaulum*)	21.5	21.5	21.5
Tufted hairgrass (*Deschampsia cespitosa*)	21.5	21.5	21.5
Muttongrass (*Poa fendleriana*)	21.5	21.5	21.5
Spike trisetum (*Trisetum spicatum*)	21.5	21.5	21.5
Forbs			
Western yarrow (*Achillea millefolium*)	21.5	21.5	21.5
Everlasting (*Antennaria* spp.)	21.5	21.5	21.5
Silky phacelia (*Phacelia sericea*)	21.5	21.5	21.5
Shrubs			
Saskatoon serviceberry (*Amelanchier alnifolia*)	21.5	21.5	21.5
Mountain big sagebrush (*Artemisia tridentata vaseyana*)	21.5	21.5	21.5
Woods rose (*Rosa woodsii*)	21.5	21.5	21.5
Subtotal	215	215	215
Total	215	430	860

The purity, viability, and germinability of purchased seed were determined by the Utah State Seed Lab using the Association of Official Seed Analysts rules for testing seeds (1981). Seeding rates were calculated using purity and germinability for purchased seeds and purity and viability for collected seeds. An additional 20 percent was factored into seeding rates for collected seeds to account for variable germinability.

Field Application

Study plots were installed the last week of September 1984. Site preparation prior to planting included ripping to a depth of 75 cm, removing large rocks, and harrowing. Before planting, seeds were mixed with rice hulls to a total volume of 10 liters. Mixtures were then sown by hand on an individual replication basis. Fertilizer was also applied by hand. A Brillion seeder-packer was used to pack the seed into the seedbed. The study area was fenced to prevent cattle grazing.

Data Collection and Analysis

In the summer of 1985, 10 rectangular quadrats 0.25 m^2 were permanently located within each replication of each treatment using a stratified random method (Chambers and Brown 1983; Knight 1978). Vegetation attributes measured included density, peak standing crop biomass, and cover. Density, defined as the number of plants of each species rooted in a quadrat, was assessed to evaluate the relationship between seeding rate and initial establishment. Because of the problems associated with identifying individual plants, density data were collected only during the first growing season (1985) when it was relatively easy to identify individuals.

I assessed standing crop biomass for each species after peak production in 1985, 1986, and 1987 using a weight-unit estimation method (Carpenter and others 1984). Weight-unit estimation was performed inside each of the 10 permanent quadrats within a replication; in addition, a verification quadrat was clipped within each replication but outside of the permanent quadrats. Samples were dried at 60 °C for 24 h. Standing crop data were collected for seeded species and for colonizer species that were not seeded.

Prior to sampling density and standing crop biomass, I determined cover from 35-mm slides taken of each permanent quadrat. These slides were projected onto a 100-square grid and estimates were made of the areas occupied by five cover classes: aerial vegetation cover, litter, bare-ground, gravel (2 mm to 7.6 cm), and rock (>7.6 cm) (Chambers and Brown 1983).

In 1986 soils were assessed for the edaphic effects of the fertilizer treatments. Two soil cores, 7.5 cm in diameter by 10 cm deep, were collected for each replication of each treatment ($n = 6$). The soils were analyzed by A and L Labs of Omaha, NE, for concentrations of N, P, and K. A specific ion electrode in a saturated calcium sulfate extraction was used to determine NO_3–N (Carson 1980a). Available-P was measured with the Bray-1 procedure using the Fiske-subbarrow reducing agent (Knudson 1980). Exchangeable-K was analyzed in a one normal solution of ammonium acetate adjusted to pH 7.0 (Carson 1980b).

I determined differences in density, standing crop, cover, and soil properties among treatments from standard analysis of variance (ANOVA) techniques. The density and standing crop analyses were based on a comparison of mean values for three species categories: introduced grasses, natives, and colonizers. Because time was a factor in the analysis of standing crop and cover, I used a repeated measures design and conservative degrees of freedom. Mean comparisons were performed using Fisher's Protected LSDs ($p < 0.05$) under the guidelines of Petersen (1977).

RESULTS

Preexisting site conditions had a significant impact on the results of this study. Because the study plots were in a basin, they experienced a perched water table early in the growing season as evidenced by ponded water on the surface and soil mottles. This may have had a negative effect on the seedling establishment and standing crop of all seeded species. The same introduced grasses as were seeded in the current study existed on the research plots prior to study installation from a previous revegetation effort. Although they had been sprayed with glyphosphate the previous summer, they were not completely eliminated. The existence of these grass species may have confounded the results of the seeding density treatments.

To determine the relative importance of the residual introduced grasses, I compared native species and introduced grass densities in the three seeding density treatments in year 1. Native species density varied little among treatments and averaged 8.54 plants/m^2 for the three seeding densities. Introduced grass density was 8.04, 19.40, and 21.12 plants/m^2 in the natives only, low grass density, and high grass density treatments, respectively. Thus, total density of introduced grasses relative to total density of native species in the native's only treatment was similar to that intended for the low grass density treatment. In the other two seeding treatments introduced grass density relative to native species density was intermediate between the intended low and high seeding treatments.

Density

Neither seeding density of introduced grasses nor fertilization had any significant effects on the combined seedling density of introduced grasses, native species, and colonizers during the first growing season (fig. 1). High densities of colonizers relative to those of native species and introduced grasses in the majority of treatment combinations in year 1 appeared to have an overwhelming effect on the analysis. The colonizers had significantly higher densities than either the introduced grasses or native species ($p < 0.05$). Deleting the colonizer species from the overall analysis resulted in significant differences among the three seeding densities and between the

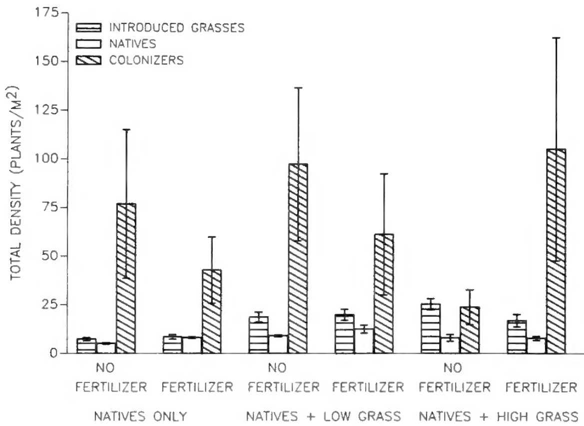

Figure 1—Total density of introduced grasses, natives, and colonizers for 1985 in research plots that were seeded with natives and a zero, low, or high level of introduced grasses and then either fertilized or not fertilized. Values are mean ± S.E., *n* is variable.

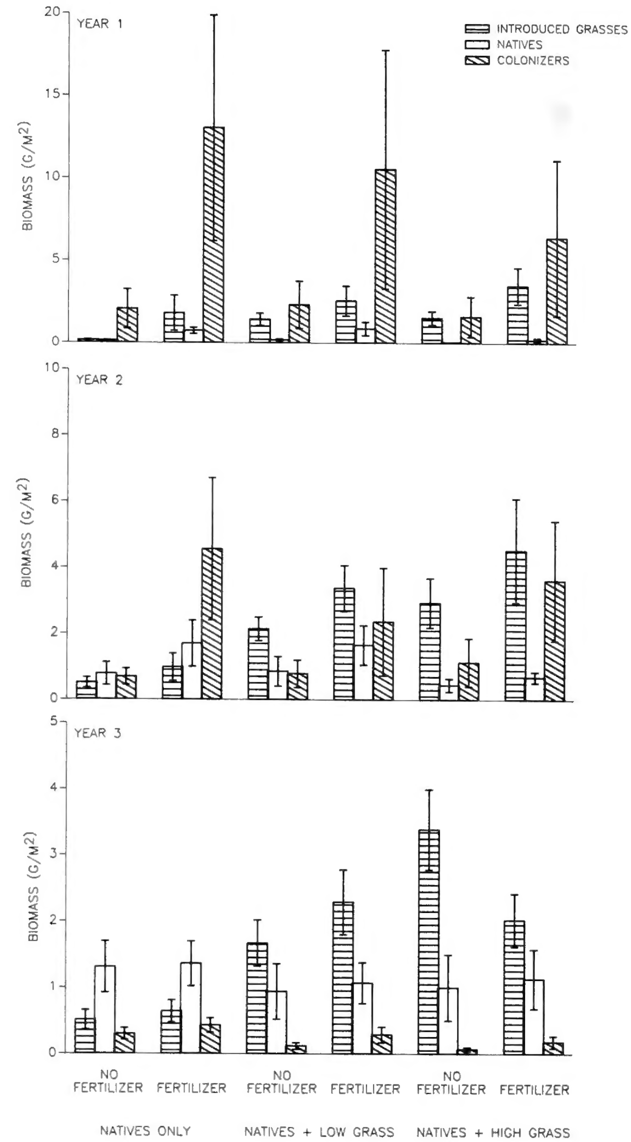

Figure 2—Dry weight biomass of introduced grasses, natives, and colonizers for 1985, 1986, and 1987 in research plots that were seeded with natives and a zero, low, or high level of introduced grasses and then either fertilized or not fertilized. Values are mean ± S.E., *n* is variable.

introduced grasses and native species (both $p < 0.001$). But there were still no statistical differences attributable to fertilizer. The two seeding treatments that included introduced grasses had higher combined densities of introduced grasses and natives than the natives-only treatment ($p < 0.05$). Because of the residual introduced grasses on the study area, there were no differences between native species and introduced grass densities in the natives-only treatment. However, introduced grass densities were higher than those of native species in the high and low grass density treatments ($p < 0.05$), but not different between the latter two treatments ($p < 0.05$).

Standing Crop Biomass and Individual Species Responses

Figure 2 and table 2 detail the highly significant differences in standing crop biomass among species categories ($p < 0.01$), between fertilizer treatments ($p < 0.001$), and among years ($p < 0.001$). Few significant effects were attributable to grass seeding density. In contrast to the density results, introduced grass standing crop biomass increased with each increase in grass seeding density ($p < 0.05$). Native species showed no differences in standing crop among the three seeding densities and colonizer standing crop decreased with each increase in seeding density ($p < 0.05$).

Total standing crop biomass decreased significantly over time ($p < 0.001$) primarily due to a decline in colonizer species productivity from year 1 through year 3. The effects of fertilizer were not consistent among species categories or over time. Introduced grasses, native species and colonizers had significantly higher standing crop in fertilized than in unfertilized treatments in year 1 ($p < 0.05$). However, by year 3 there were no differences between fertilized and unfertilized treatments for any of the species categories ($p < 0.05$). For introduced grasses standing crop decreased between years 1 and 3 in fertilized treatments, but increased in unfertilized treatments ($p < 0.05$). Standing crop of native species did not change over time in fertilized treatments, but increased between years 1 and 3 in unfertilized treatments ($p < 0.05$). Colonizer standing crop decreased significantly over time in both fertilized and unfertilized treatments.

Table 2 shows that first and third year standing crop biomass of intermediate wheatgrass, smooth brome, and orchardgrass were higher than those of meadow foxtail and Timothy. This may be attributable to differences in the initial densities of residual individuals of these species. By year 3 standing crop biomass of slender wheatgrass greatly exceeded that of the other native

Table 2—Standing crop biomass (g/m² dry weight) of species occurring in unfertilized and fertilized plots in years 1 and 3

Species	Year 1		Year 3	
	No fertilizer	Fertilizer	No fertilizer	Fertilizer
Introduced grasses				
Intermediate wheatgrass (*Agropyron intermedium*)	[1]1.68 ± 0.327 (3)[2]	3.97 ± 0.475 (6)	2.18 ± 0.134 (7)	2.81 ± 0.196 (7)
Meadow foxtail (*Alopecurus pratensis*)	.06 ± .002 (5)	.07 ± .007 (4)	1.33 ± .117 (6)	1.10 ± .078 (6)
Smooth brome (*Bromus inermis*)	1.19 ± .058 (7)	2.53 ± .100 (6)	3.18 ± .179 (8)	1.80 ± .051 (7)
Orchardgrass (*Dactylis glomerata*)	.92 ± .080 (8)	3.22 ± .182 (8)	2.65 ± .249 (9)	2.42 ± .202 (9)
Timothy (*Phleum pratense*)	.16 ± .010 (4)	.70 ± .036 (5)	.78 ± .052 (8)	1.06 ± .050 (8)
Native species				
Grasses				
Slender wheatgrass (*Agropyron trachycaulum*)	—	—	2.00 ± .170 (8)	1.99 ± .109 (9)
Tufted wheatgrass (*Deschampsia cespitosa*)	.04 ± .004 (5)	.11 ± .009 (2)	.70 ± .070 (8)	.62 ± .049 (6)
Muttongrass (*Poa fendleriana*)	.18 ± .011 (4)	.55 ± .060 (4)	.22 ± .021 (3)	.45 ± .043 (7)
Spike trisetum (*Trisetum spicatum*)	—	—	—	—
Forbs				
Western yarrow (*Achillea millefolium*)	.14 ± .009 (9)	.92 ± .077 (9)	2.65 ± .023 (7)	.21 ± .009 (6)
Antennaria (*Antennaria* spp.)	—	—	.07 ± .002 (2)	.24 ± .000 (1)
Silky phacelia (*Phacelia sericea*)	.01 ± .000 (1)	.15 ± .000 (1)	.14 ± .004 (4)	—
Shrubs				
Saskatoon serviceberry (*Amelanchier alnifolia*)	.20 ± .000 (1)	—	.24 ± .000 (1)	—
Mountain big sagebrush (*Artemisia tridentata vaseyana*)				
Woods rose (*Rosa woodsii*)	.03 ± .005 (2)	.03 ± .005 (2)	.32 ± .026 (4)	.06 ± .000 (1)
Colonizer species				
Winter bentgrass (*Agrostis scabra*)	—	—	.27 ± .021 (3)	.51 ± .111 (3)
Idaho fescue (*Festuca idahoensis*)	.01 ± .00 (1)	—	—	—
Poa (*Poa* spp.)	—	.21 ± .000 (1)	—	—
Alkali sandspurry (*Spergularia diandra*)	5.61 ± .427 (9)	30.23 ± 2.103 (9)	.40 ± .041 (7)	.46 ± .026 (9)
Spreading groundsmoke (*Gayophytum diffusum*)	.21 ± .020 (9)	.20 ± .017 (7)	.11 ± .017 (7)	.26 ± .027 (7)
Prostrate knotwood (*Polygonum aviculare*)	.28 ± .024 (9)	1.38 ± .093 (9)	.11 ± .013 (3)	.23 ± .042 (4)
Draba (*Draba* spp.)	—	.18 ± .031 (2)	.08 ± .005 (3)	.06 ± .000 (1)
Common fireweed (*Epilobium angustifolium*)	—	—	.02 ± .002 (2)	.08 ± .016 (3)
Aster (*Aster* spp.)	—	—	.24 ± .000 (1)	—
Common dandelion (*Taraxacum officinale*)	—	—	.06 ± .000 (1)	—
Lodgepole pine (*Pinus contorta*)	—	—	.12 ± .016 (4)	.06 ± .000 (3)

[1]Values are mean ± S.E.
[2]Number of observations.

grasses. The apparent absence of slender wheatgrass from the study plots in year 1 may have resulted from sampling error; seedlings were extremely difficult to identify during the first year, and slender wheatgrass may have been misidentified or placed in an *Agropyron* species category. Spike trisetum was not observed in the sample plots in year 1 or year 3. Both muttongrass and tufted hairgrass were present in a high number of sample plots in year 3. The seeded native forbs all occurred in the study plots by year 3, but only western yarrow was found in a high number of sample quadrats. Establishment of the seeded native shrubs was poor with only a few individuals of Saskatoon serviceberry and Woods rose occurring in the sample plots. Colonizer dominants in year 1 were alkali sandspurry, spreading groundsmoke, and prostrate knotweed. By year 3 individuals of winter bentgrass, draba, common fireweed, aster, common dandelion, and lodgepole pine were also recorded.

In general, the effects of fertilizer on individual species were the same as those observed in the combined species analyses. Standing crop biomass of most species was higher in fertilized than in unfertilized plots in year 1. In year 3 standing crop biomass was either less in fertilized than in unfertilized plots or exhibited a relatively lesser increase in fertilized than in unfertilized plots.

Cover

Results of the cover data analysis followed the same trends as those of the standing crop biomass analysis (fig. 3). There were no significant differences in the cover classes that were attributable to grass seeding density. Fertilization resulted in higher vegetation cover and lower bare ground cover in the combined 3-year analysis (both, $p < 0.001$). Differences existed among years for all of the cover classes, except vegetation ($p < 0.05$ to $p < 0.001$). The response to fertilizer was not consistent over time. In treatments that were unfertilized, vegetation cover increased between years 1 and 3, while litter and bare ground remained unchanged and rock increased ($p < 0.05$). Treatments that were fertilized showed significant yearly decreases in vegetation cover and increases in litter, bare ground, and rock ($p < 0.05$).

Soil Properties

Two years after the study plots had been fertilized, there were no significant differences in either soil NO_3–N or exchangeable K between fertilized and unfertilized treatments (table 3). However, significantly higher levels of available P existed in fertilized than in unfertilized treatments ($p < 0.01$).

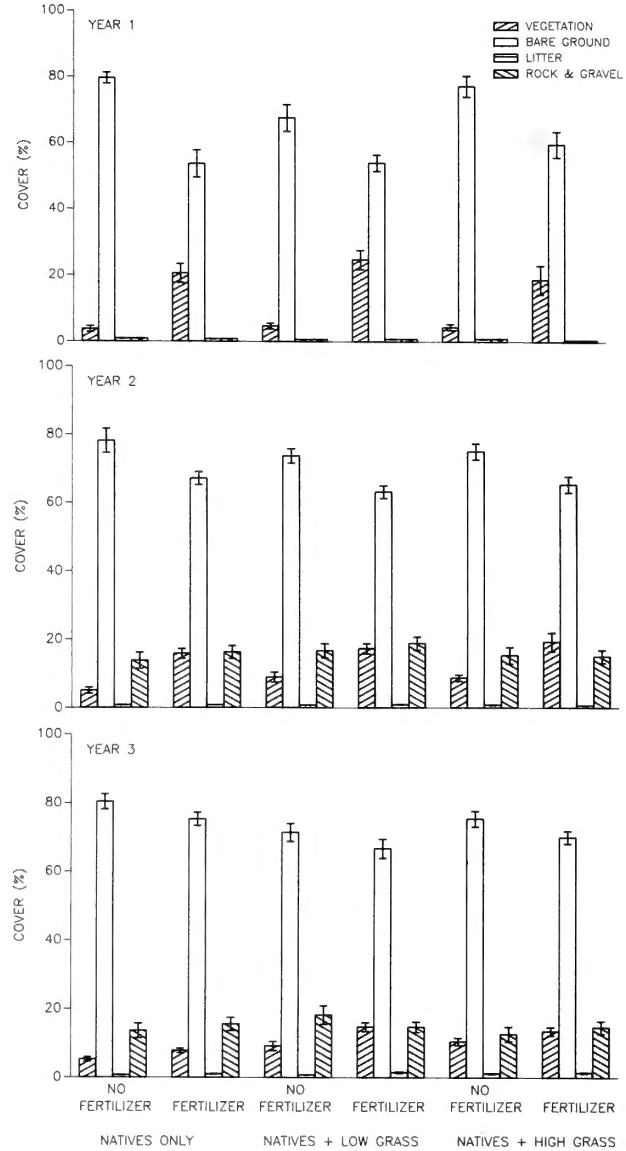

Figure 3—Percentage cover by cover class for 1985, 1986, and 1987 in research plots that were seeded with natives and a zero, low, or high level of introduced grasses and then either fertilized or not fertilized. Values are mean ± S.E., $n = 30$.

Table 3—Levels of soil nutrients on the study plots 2 years after fertilization

Variable	Fertilized	Not fertilized	
NO_3–N (mg/kg)	[1]5.8 ± 0.22	5.8 ± 0.14	NS[2]
P (mg/kg)	26.7 ± 2.74	18.0 ± 1.31	0.01
K (mg/kg)	66.1 ± 4.08	66.3 ± 3.37	NS

[1]Values are mean ± S.E., $n = 9$.
[2]Significance levels for differences between treatments from ANOVA's.

DISCUSSION

This section discusses the three null hypotheses I set out in the Introduction section. Also, reclamation strategies based on the research may prove helpful to land managers.

Hypothesis 1

Increasing density of introduced grasses did not lower establishment or growth of the native species. These findings are contrary to those of studies in which higher seeding densities have decreased species diversity due to increased interspecific competition and competitive exclusion of less "vigorous" native species (Holecheck and others 1981). The results of the current study may be partly explained by the poor establishment of seeded species in general. Densities of the introduced grasses and natives may have been insufficient for significant competitive interactions to occur. The colonizers did exhibit decreases in standing crop with increases in grass seeding density and may have been more sensitive to the competitive effects of the introduced grasses than the native species. In turn, the abundance of the colonizer, alkali sandspurry, in year 1 may have negatively affected establishment of both introduced grasses and native species.

The high variability in species establishment may have been related more to establishment requirements and site characteristics than to introduced grass seeding density. The saturated soils of the study area early in the growing season may have favored germination and establishment of species adapted to moister edaphic conditions. Tufted hairgrass, muttongrass, and western yarrow occur on both disturbed areas and semiwet meadows near the study site and established in relatively high densities. Species such as spike trisetum, antennaria, silky phacelia, Saskatoon serviceberry, and mountain big sagebrush exist as colonizers on disturbed areas but almost never occur in semiwet meadows. The poor estabishment of these species may indicate a low tolerance to saturated soils.

Hypotheses 2 and 3

Fertilization did not have a larger positive effect on the 3-year establishment and growth of the introduced grasses than of the native species. Because increasing introduced grass density had no effect on native species establishment, hypothesis 3 could not be tested. Introduced grasses, native species, and colonizers all showed large initial responses to fertilizer. However, after levels of soil nutrients had decreased in the fertilized treatments, introduced grasses exhibited a larger relative decrease in standing crop biomass than native species, and colonizers had the largest decrease of all. In the unfertilized treatment, native species had greater increases in standing crop biomass than introduced species. Perennial introduced grasses frequently exhibit rapid growth rates and high nutrient uptake efficiencies but maximum expression of these characteristics is obtained only at relatively high nutrient levels (Chapin 1980). Thus, these species show large responses to fertilizers but require sustained nutrient levels to maintain high levels of productivity. Many native species are adapted to lower nutrient levels and exhibit slower growth rates and lower nutrient uptake efficiencies (Chapin 1980). In general, they show smaller responses to fertilizers and can maintain productivity, albeit at lower levels, with lower levels of nutrients.

The pattern of rapid invasion followed by precipitous decline exhibited by the colonizer, alkali sandspurry, has been observed in other ecosystems for different species (Allen and Allen 1984; Allen and Knight 1984; Redente and Cooke 1986). Immediately following disturbance, availability of nutrients, especially N, can be high depending upon the type of disturbance and the stage of soil development (Tilman 1985; Vitousek and others 1979). Fertilization during reclamation can exacerbate these results. Many early successional species exhibit rapid establishment and growth during this phase, but are rapidly excluded as levels of nutrients decrease and competition from later successional species increases.

The rapid decline in plant available N and K was largely determined by soil nutrient dynamics. A portion of the nutrients added to the site through fertilization may have been taken up by the colonizer species in year 1 and tied up in their undecomposed litter in years 2 and 3. However, the soil on the site had inherently low nutrient retention capacity as characterized by a high portion of coarse materials (33.5 percent), low cation exchange capacity (3.2 meq/100g), and low amount of organic matter (0.4 percent). Precipitation in the study area is relatively high and may contribute to low retention of mobile nutrients. Fertilization of these soils resulted in a pulse of nutrients to the system during the first growing season followed by a rapid decline in the mobile nutrient N and to a lesser extent K. Phosphorus is less mobile and higher levels were maintained over time.

Reclamation Strategies

Methods used in the reclamation of nutrient deficient soils, such as those in this study, should be determined by the site's inherent regenerative capacity and the desired end land use. If the objective of revegetation of similar drill pad sites in the area is reestablishment of lodgepole pine, and if relatively low biomass production of grasses and forbs is acceptable in the interum, then fertilization may not be necessary and species adapted to low levels of nutrients should be seeded. Fertilization of nitrogen deficient soils does not alter the soil characteristics or decrease the deficiency (Bloomfield and others 1982). This and other studies (see Chapin 1980) indicate that native species adapted to low nutrient conditions can maintain more constant productivity on low nutrient soils than high-nutrient adapted introduced species. The N status of nutrient deficient soils has often been improved by seeding species with nitrogen-fixing symbionts (Bloomfield and others 1982; Jeffries and others 1981). A legume, northern sweetvetch (*Hedysarum boreale*), performed well in separate study plots on the site and may be beneficial on similar sites. On sites with P or micronutrient deficiency, fertilization with these elements may increase establishment and productivity.

If the objective in revegetating these sites is to increase biomass production of grasses or forbs and to perhaps slow reestablishment of lodgepole pine, then treatments that increase the nutrient retention capacity of the soil and accelerate the development of a viable nutrient cycle may be necessary. Topsoil is typically used in revegetation to provide a growing medium and to accelerate soil development. However, addition of selected organic amendments may be equally or more effective in soil development than more expensive topsoil/mulch procedures (Elkins and others 1984; Scholl and Pace 1984; Woods and Schuman 1986). Once the nutrient retention capacity of the soil has been improved, it is possible to seed a higher proportion of high-nutrient adapted species and thereby increase biomass production. In addition, on sites with relatively greater nutrient retention capacities, fertilization may have a larger effect on plant establishment and production. Including low-nutrient adapted species and species with N-fixing symbionts on these sites will increase species diversity and may still help to ensure their sustained productivity.

REFERENCES

Association of Official Seed Analysts. 1981. Rules for testing seeds. Journal of Seed Technology. 6(2): 1-125.

Allen, E. B.; Allen, M. F. 1984. Competition between plants of different successional stages: mycorrhizae as regulators. Canadian Journal of Botany. 62: 2626-2629.

Allen, E. B.; Knight, D. H. 1984. The effects of introduced annuals on secondary succession in sagebrush-grassland, Wyoming. The Southwestern Naturalist. 28: 407-421.

Aldon, E. F.; Springfield, H. W.; Scholl, D. G. 1976. Fertilizer response of alkali sacaton and fourwing saltbush grown on coal mine spoil. Res. Note RM-306. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Bengeyfield, P.; Elsea, J.; Hennes, B.; Kappesser, G.; Potyondy, J. 1980. East Fork Smiths Fork barometer watershed. Volume I: data interpretations and summaries. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; Final Report. 56 p.

Berg, W. A. 1980. Nitrogen and phosphorus fertilization of mined land. In: Adequate reclamation of mined land? A symposium. Billings, MT: Soil Conservation Society of America and Western Regional Coordinating Committee for Disturbed Land Reclamation. 8 p.

Bloomfield, H. E.; Handley, J. F.; Bradshaw, A. D. 1982. Nutrient deficiencies and the aftercare of reclaimed derelict land. Journal of Applied Ecology. 19: 151-158.

Brown, R. W.; Johnston, R. S.; Chambers, J. C. 1984. Responses of seeded native grasses to repeated fertilizer applications on acidic alpine mine spoils. In: Colbert, T. A.; Cuany, R. L., eds. High altitude revegetation workshop No. 7. Fort Collins, CO: Colorado State University, Water Resources Research Institute: 200-214.

Carpenter, A. T.; Johnson, P. S.; Squibb, R. C. 1984. Nondestructively estimating phytomass of shrubs and herbs. Paper presented at the 1984 annual meeting of the Society for Range Management; Bismark, SD.

Carson, P. L. 1980a. Recommended nitrate-nitrogen tests. In: Dahnke, W. C., ed. Recommended chemical soil test procedures for the North Central Region. Bull. 499. Fargo, ND: North Dakota State University, North Dakota Agricultural Experiment Station: 12-30.

Carson, P. L. 1980b. Recommended potassium test. In: Dahnke, W. C., ed. Recommended chemical soil test procedures for the North Central Region. Bull. 499. Fargo, ND: North Dakota State University, North Dakota Agricultural Experiment Station: 17-21.

Chambers, J. C.; Brown, R. W. 1983. Methods for vegetation sampling and analysis on revegetated mined lands. Gen. Tech. Rep. INT-151. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 57 p.

Chapin, F. S., III. 1980. The mineral nutrition of wild plants. Annual Review of Ecology and Systematics. 11: 233-260.

DePuit, E. J.; Coenenberg, J. G. 1979. Responses of revegetated coal strip mine spoils to variable fertilization rates, longevity of fertilization program, and season of seeding. Res. Pap. 150. Bozeman, MT: Montana State University, Montana Agricultural Experiment Station. 81 p.

DePuit, E. J.; Willmuth, W. H.; Coenenberg, J. G. 1978. Research on revegetation of surface mined lands at Colstrip, Montana: progress report: 1975-1977. Res. Pap. 127. Bozeman, MT: Montana State University, Montana Agricultural Experiment Station. 165 p.

Elkins, N. Z.; Parker, L. W.; Aldon, E.; Whitford, W. G. 1984. Responses of soil biota to organic amendments in stripmine spoil in Northwestern New Mexico. Journal of Environmental Quality. 13(2): 215-219.

Hanson, C. L.; Schumaker, G. A.; Erickson, C. J. 1976. Influence of fertilization and supplemental water runoff on production and nitrogen content of western wheatgrass and smooth brome. Journal of Range Management. 29(5): 406-409.

Harper, J. L. 1977. Population biology of plants. New York: Academic Press. 892 p.

Hodder, R. L.; Sindelar, B. W.; Bucholz, J.; Ryerson, D. E. 1972. Coal reclamation research, location - Western Energy Company, Coalstrip, Montana. Res. Rep. 20. Bozeman, MT: Montana State University, Montana Agricultural Experiment Station. 45 p.

Holechek, J. L.; DePuit, E. J.; Coeneberg, J. G.; Valdez, R. 1981. Fertilizer effects on establishment of two seed mixtures on mined land in southeastern Montana. Journal of Soil and Water Conservation. 36: 241-244.

Houston, R. W.; Hyder, D. N. 1975. Ecological effects and the fate of N following massive N fertilization of mixed-grass plains. Journal of Range Management. 28(1): 56-60.

Jeffries, R. A.; Bradshaw, A. D.; Putwain, P. D. 1981. Growth, nitrogen accumulation and nitrogen transfer by legume species established on mine spoils. Journal of Applied Ecology. 18: 945-965.

Knight, D. H. 1978. Methods of sampling vegetation: an instruction manual. Laramie, WY: University of Wyoming, Ark Industries. 87 p.

Knudson, D. 1980. Recommended phosphorus tests. In: Dahnke, W. C., ed. Recommended chemical soil test procedures for the North Central Region. Bull. 499. Fargo, ND: North Dakota State University, North Dakota Agricultural Experiment Station: 14-16.

McNaughton, S. J. 1977. Diversity and stability of ecological communities: a comment on the role of empiricism in ecology. The American Naturalist. 3(979): 515-525.

Mellinger, M. V.; McNaughton, S. J. 1975. Structure and function of successional vascular plant communities in central New York. Ecological Monographs. 45(2): 161-182.

Moore, R. P. 1972. Tetrazolium staining for assessing seed quality. In: W. Heydecker, ed. Seed Ecology. University Park, PA: Pennsylvania State University Press: 346-366.

Petersen, R. G. 1977. Use and misuse of multiple comparison procedures. Agronomy Journal. 69: 205-208.

Redente, E. F.; Cook, C. W. 1986. Structural and functional changes in early successional stages of a semiarid ecosystem. Fort Collins, CO: Colorado State University Research Report to U.S. Department of Energy, DOE/EV/04018-9.

Root, R. B. 1973. Organization of plant-arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*). Ecological Monographs. 43(1): 95-124.

Scholl, D. G.; Pase, C. P. 1984. Wheatgrass response to organic amendments and contour furrowing on coal mine spoil. Journal of Environmental Quality. 13(3): 479-482.

Southwood, R. T. E.; Brown, V. K.; Reader, P. M. 1979. The relationship of plant and insect diversities in succession. Biological Journal of the Linnean Society. 12: 327-348.

Tahvanainen, J. O.; Root, R. B. 1972. The influence of vegetational diversity on the population ecology of a specialized herbivore, *Phyllotreta cruciferae* (Coleoptera: Chrysomelinae). Oecologia. 10: 321-346.

Teidemann, A. R.; Lopez, C. F. 1982. Soil nutrient assessments of mine spoils: In: Aldon, E. F.; Oaks, W. R., eds. Reclamation of mined lands in the Southwest: a symposium. Albuquerque, NM: Soil Conservation Society of America - New Mexico Chapter: 66-79.

Thornburg, A. A. 1982. Plant materials for use on surface-mined lands in arid and semiarid regions. SCS TP-157. EPA 600-7-79-134. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 88 p.

Tilman, D. 1985. The resource-ratio hypothesis of plant succession. The American Naturalist. 125(6): 827-852.

Tisdale, S. L.; Nelson, W. L. 1975. Soil fertility and fertilizers. 3d ed. New York: Macmillan Publishing. 694 p.

U.S. Department of Agriculture, Forest Service. 1979. User's guide to vegetation: mining and reclamation in the West. Gen. Tech. Rep. INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 85 p.

Vitousek, P. M.; Gosz, J. R.; Grier, C. C.; Melillo, J. M.; Reiners, W. A.; Todd, R. L. 1979. Nitrate losses from disturbed ecosystems. Science. 204: 469-474.

Woods, L. E.; Schuman, G. E. 1986. Influence of soil organic matter concentrations on carbon and nitrogen activity. Soil Science Society of America Journal. 50: 1245-1251.

Chambers, Jeanne C. 1989. Native species establishment on an oil drill pad site in the Uintah Mountains, Utah: effects of introduced grass density and fertilizer. Res. Pap. INT-402. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 9 p.

This study examined the effects of introduced grass seeding density and fertilizer on native species establishment on an oil drill pad site in the Uintah Mountains, UT. Differences in first-year seedling density and 3-year standing crop biomass among treatments were evaluated for seeded introduced grasses and native species and for unseeded colonizers. Aerial cover was measured all 3 years and the effects of fertilization on soil NO_3—N, available P, and exchangeable K were examined 2 years after application. Recommendations for reclamation of similar sites are given.

KEYWORDS: reclamation, revegetation, fertilization, seeding density, introduced grasses

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